



**FP7 project  
Strengthening Railway Vehicles Centre of  
Faculty of Mechanical Engineering Kraljevo**

## **Deliverable D1**

**Activity report:  
Secondments for experimental methods  
of railway vehicles dynamics**

Faculty of Mechanical Engineering Kraljevo  
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## Basic data

### Project data

Classification:	FP7 CSA project, area "Sustainable Surface Transport"
Call:	REGPOT-2007-1
Title:	Strengthening Railway Vehicles Centre of Faculty of Mechanical Engineering Kraljevo
Acronym:	SeRViCe
Number:	206929

### Deliverable data

Code:	D1
Work package:	WP1-"Knowledge"
Dissemination level:	Public
Lead beneficiary:	Faculty of Mechanical Engineering Kraljevo

## Introduction

Deliverable D1, "Secondments for experimental methods of railway vehicles dynamics" is a result of activities of Faculty of Mechanical Engineering Kraljevo (in the text that follows: MFKV) and DIEM department of University of Bologna (in the text that follows: DIEM) carried out within WP-1 "Knowledge". The activities contributed to extending of the experiences and improvement of knowledge of researchers from Railway Vehicles Center of Faculty of Mechanical Engineering Kraljevo (in further text: RVC), and thus, to the ultimate project goal of rebuilding of the Center as modern research institution and part of integrated ERA.

Workpackage WP-1 comprises, among other activities that contributed to the improvement of knowledge of present MFKV staff, two-way secondments of researchers in fields of theoretical and experimental methods of railway vehicles dynamics and in the field of fatigue of mechanical structures and components. The idea of the secondments is to give to researchers from MFKV opportunity to work in environment of prominent European research institution, learning not only about contemporary scientific problems and research methods, but also about organization of research work, project management and other topic connected to scientific management.

Secondments on experimental methods in railway engineering are activity of the project which was focused on improving the knowledge and skills of MFKV researchers in field of measurement systems, experimental techniques and experimental data processing, with the final goal to support further development of experimental methods for investigation of railway vehicles. The secondments are complementary activity with secondments in area of theoretical methods of railway dynamics and secondments in field of fatigue of mechanical structures and components.

By the project plan, the activity "Two-way secondments for development of measurement techniques in railway vehicles dynamics" was planned to start in the third project month and to end in 32<sup>nd</sup> project month. Planned engagement on the project activity was 14 research-months. The planned timeline for this deliverable was the end of 34<sup>th</sup> project month.

## Description

### Concept

The concept of the work during secondments was developed by Director of DIEM laboratory, prof. dr Giangiacomo Minak. In the initial project concept, secondments in the field of experimental methods of railway dynamics were planned to be carried out with auxiliary project partners, company Mer Mec from Bari (Italy) and Institute for Sensor and Actuator Systems from Vienna (Austria). However, the partners did not succeed in organization of the secondments, and DIEM department offered help in the situation. This line of events later turned out to be of positive effect to the whole workpackage WP-1 "Knowledge", because it enabled harmonization of activities carried out on secondments in field of experimental dynamics with secondments in the field of investigations of fatigue of mechanical structures and components. The researchers included in those activities present core of the teams that prepared successful application for projects which are legacy of project "SeRViCe".

The concept of the secondments was to include seconded researcher from MFKV into experimental investigations of mechanical structures that included two experimental techniques relevant for experimental research of dynamics of railway vehicles:

- application of strain sensors with wireless data transfer,
- experimental research of impacts at low velocities.

In course of the project activities arose another research problem which attracted attention of researchers from both institutions, namely data processing in conditions of heavy data transmission

losses, and that task was the topic of research carried out during secondments carried out both at DIEM and MFKV.

Besides the research activities, a lot of work was dedicated to development of new projects that will provide sustainability to the results of "SeRViCe" project and projects that capitalized on the results of the project "SeRViCe". Majority of the projects were intended to support the improvement of industry, but some of the projects were intended to support of development of university and education processes.

Seconded researchers were also included in regional projects of technology transfer and life-long education. The idea of these activities was to introduce MFKV researchers to the concept of utilization of advanced knowledge in practice. Furthermore, it was the focal point of engagement of DIEM researchers during their secondments at MFKV.

Finally, secondments were used also for purposes of public promotion of project results, widening of networks of contacts with industry and universities on both sides, and for visits to cultural and historic monuments in both countries.

## Seconded staff

MFKV provided one researcher for the secondments in field of experimental investigations of railway dynamics, dr Zlatan Šoškić, electrical engineer, who was for a decade in charge for development of measurement equipment and data processing in Railway Vehicles Center of MFKV. While experienced in measurement and data processing software development, he did not have previous experiences in some of modern experimental techniques, including wireless data transfer, and investigations of novel materials, including composite materials.

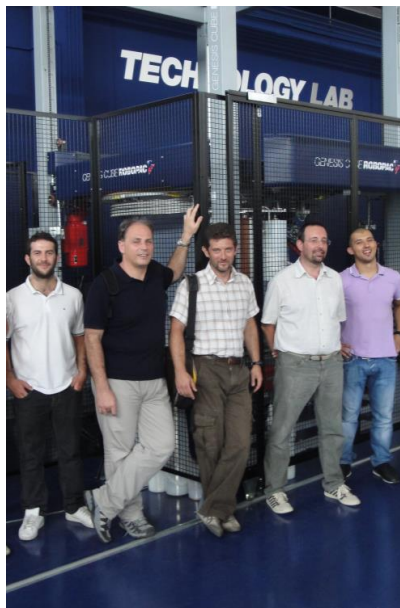


Fig.1 Team that carried out secondments in field of experimental dynamics during experimental campaign in company Robopac, Rimini, July 2010, from left to right A.Radovani, Z.Šoškić, G.Minak, C.Fragassa and E.Maione

DIEM provided five researchers for the secondments, under the leadership of prof. dr Giangiacomo Minak, director of DIEM laboratory. Associated researchers were Emiliano Maione, Ricardo Pancirolli and Asti Radovani, mechanical engineers participating in experimental mechanics program of DIEM. In the team was also Dr Cristiano Fragassa, a mechanical engineer who is in charge for project development in DIEM.

## Agenda

The secondments in field of experimental methods of mechanical engineering included the tasks presented in the following table:

Task no.	Start date	End date	Engagement (res-mon)	Name of researcher	Domicile institution	Host institution
1	29.12.2008	11.1.2009	0.5	<i>C. Fragassa</i>	DIEM	MFKV
2	8.3.2009	20.3.2009	0.5	<i>Z. Šoškić</i>	MFKV	DIEM
3	10.4.2009	24.4.2009	0.5	<i>C. Fragassa</i>	DIEM	MFKV
4	20.6.2009	18.7.2009	1	<i>Z. Šoškić</i>	MFKV	DIEM
5	11.8.2009	10.9.2009	1.25	<i>C. Fragassa</i>	DIEM	MFKV
6	29.9.2009	13.10.2009	0.5	<i>C. Fragassa</i>	DIEM	MFKV
7	17.10.2009	1.11.2009	0.5	<i>Z. Šoškić</i>	MFKV	DIEM
8	15.1.2010	15.2.2010	1	<i>Z. Šoškić</i>	MFKV	DIEM
9	1.7.2010	22.7.2010	0.75	<i>Z. Šoškić</i>	MFKV	DIEM
10	20.8.2010	3.9.2010	0.5	<i>E. Maione</i>	DIEM	MFKV
11	20.8.2010	3.9.2010	0.5	<i>A. Radovani</i>	DIEM	MFKV
12	24.9.2010	15.10.2010	0.75	<i>Z. Šoškić</i>	MFKV	DIEM
13	13.11.2010	27.11.2010	0.5	<i>Z. Šoškić</i>	MFKV	DIEM
14	1.12.2010	15.12.2010	0.5	<i>G. Minak</i>	DIEM	MFKV
15	31.1.2011	28.2.2011	1	<i>Z. Šoškić</i>	MFKV	DIEM
16	18.3.2011	1.4.2011	0.5	<i>Z. Šoškić</i>	MFKV	DIEM
17	25.4.2011	30.4.2011	0.25	<i>G. Minak</i>	DIEM	MFKV
18	25.4.2011	30.4.2011	0.25	<i>R. Pancirolli</i>	DIEM	MFKV
19	25.4.2011	30.4.2011	0.25	<i>A. Radovani</i>	DIEM	MFKV

## Content of the work

### Methods for wireless data transfer in experimental investigations of mechanical structures

Modern experimental **research of railway vehicles dynamics are focused to measurements of forces between wheels and rails**. The forces are usually measured by the extensimetric principle, and **the most challenging task** in design of equipment for measurement of forces in the contact between wheel and rail is **transfer of the measured signal**, because the strain gauges, used as force transducers, are placed on the rotating wheel. Method of commutation, used for decades for transmission of signals from rotating to stationary parts, causes a lot of electronic noise because of electromagnetic induction, and this is the reason for recent move towards **wireless transmission**.

Prior to the project "SeRViCe", **researchers from MFKV did not have any experience in design of measurements based on wireless data transmission**. For that reason, in period July 2010-October 2010, **a researcher from MFKV was included in an industrial project that used simple, but powerful method for wireless measurements** of strain of a rotating ring of a mechanical structure.

The research, carried out by DIEM, was performed in order to reduce vibrations of a packing machine. The machine has a coil with the wrapping foil mounted on a horizontal ring that performs rotation in horizontal plane. The ring is supported by horizontal frame to which it is connected by six wheels that enable the rotation of the ring. During a packing cycle, the frame itself performs vertical translation once downwards and once upwards, carrying the ring with it. Thus the foil, which is connected to the load before wrapping, wraps the whole load which is placed inside the space enclosed by the ring during motion. Rotation of the ring and translation of the frame are driven by two electric motors, and the appropriate electronic control equipment is mounted on the ring as a counterweight for the coil with the wrapping foil. In exploitation conditions, customers observed vibrations of the frame around horizontal axes.

Among other experimental and numerical studies, measurements of strains arising in selected points of the rotating ring and the supporting frame were performed.



Fig.2 System for wireless measurements of strain SG Link

For the sake of experimental analysis of dynamical behavior of the considered machine, measurements of the strains, arising on the structure during various experimental and exploitation regimes, were performed. Experiment with 25 total test runs was designed with intention to provide data for analysis of influence of the following parameters: rotation speed of the rotating ring, mass of foil drum and foil stretching force. Strains were measured with standard strain gauges having resistance  $120.0 \pm 0.5 \, \Omega$  and strain gauge factor  $2.04 \pm 0.01$ , and the electric signal proportional to the strain was "in situ" conditioned and converted to digital form by microprocessor attached in proximity of the strain gauge. The digital signal was then transmitted through wireless network to a measurement control computer. The acquisition frequency of the measurement was 100 Hz, and precise timekeeping was provided by a microprocessor, which in turn was synchronized by the control computer.

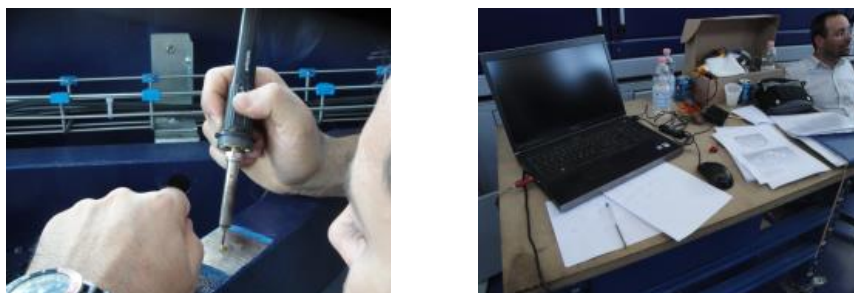


Fig. 3. Mounting of the remote unit (left) and the base station (right) of the wireless system for strain measurements, Rimini, July 2010

The system for measurements of strain (Fig. 2) that enables wireless transfer of measured data was of the main interest for the purpose of the secondments. It consists of a remote unit that is fixed to the rotating part (Fig.2 left) and a base station, which is connected to a computer for control of the measurements (Fig. 2 right). Remote unit is connected to a strain gauge mounted at the rotating part. From batteries it provides power supply to the strain gauge, and has internal resistors that provide stability and temperature compensation to strain measurements. Base unit provides

synchronization of measurement and controls wireless data transfer. One base unit may control multiple remote units, providing the scalability to the systems.

Researcher from MFKV was trained in mounting and application and data acquisition of the system for wireless strain measurements. The goal was successfully achieved during tasks 9 (July 2010) and 12 (October 2010).

### Data processing in conditions of heavy data transmission losses

A very interesting problem was discovered during data processing of the experimental data acquired during investigations on the machine described in the previous chapter.

While experimental results were free of electronic noise usually caused by commutation, they were still heavily influenced by **heavy transmission losses** (Fig.4). The losses are **caused by algorithm for data transmission**, which rejects the data that are corrupted under the influence of electromagnetic induction. The **digital data transmission** presents improvement in measurement technique in comparison to analogue data transmission, but still requests careful and skilful data processing. **Considering the fact that the observed effect is of general nature, it is expected also to occur during experimental investigations of railway vehicles dynamics**, so the research of the problem was selected to be the topic of the secondments that followed. Considering the fact that the researcher from MFKV Z. Šošković already had considerable experience in experimental data processing, he was the leader at tasks 10, 11 (August/September 2010), 14 (December 2010) and 17-19 (April 2011) that dealt with development of methods for data processing in conditions of heavy data transmission losses.

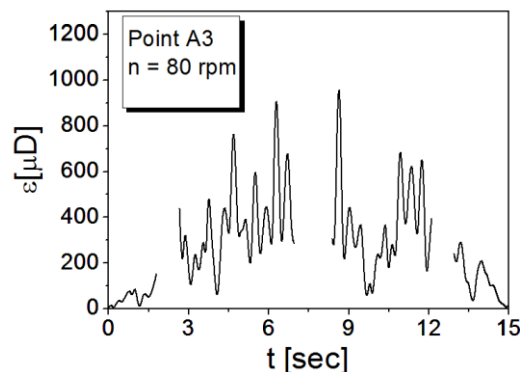


Fig.4. A typical diagram of experimentally acquired data in conditions of heavy data transmission losses

The most important result of the research work is **development of data processing procedures for frequency analysis in conditions of heavy data transmission losses**. Due to the losses caused by electromagnetic induction, the acquired measurement data were not equidistant in time, so the standard FFT analysis was not applicable. Instead, LSQ spectral analysis procedure was performed, leading to Lomb's periodogram instead of usual amplitude-frequency spectra. However, Lomb's periodogram is proportional to PSD spectra, so its application is straightforward. The only important difference that should be taken care about while analyzing Lomb's periodogram is that it represents normalized power spectra, so that conclusions about intensities of the same spectral lines in different spectra should be made carefully.

### Methods for impact testing of mechanical structures

Besides the investigations of ride safety and comfort, performed during the test rides, and crash tests, **railway vehicles are tested by impacts at low speeds**, for the sake of analyzing their behavior during forming of train compositions. **MFKV has test rig for investigations of dynamic behavior of wagons during impacts** (Fig. 5), and it was of interest for MFKV researchers to learn about the methodologies of impact testing of composite structures.





Fig. 5. Rig for impact tests of wagons in Kraljevo

Composite materials are widely used in aerospace, road and rail vehicle manufacturing sectors both for their material properties (low density, high stiffness and strength, resistance to chemical and environmental agents), structural design potentials (ability to design material with desired anisotropic mechanical properties) and manufacturing advantages (energy saving due to low production temperatures and pressures, complicated shaped components can be molded in one process rather than being assembled from components), successfully replacing not only steel, but also light alloys in mechanical structures.

The application of composite materials in mechanical engineering is limited by poor transverse and shear properties of unidirectional composites, which raise concern about their impact behavior. Being that safety is a major priority in the passenger transport sector, crash performance of vehicles is one the most important aspects of structural behavior both for manufacturers and consumers, making research of high-velocity impacts of composites relevant for vehicle industry. Besides, low-velocity impact behavior of composites is also of interest for vehicle industry because of variety of accidental hits to which parts and components of a vehicle are exposed in exploitation conditions, like it is the case with tool-dropping during manufacturing and maintenance operations. Low-velocity impact behavior has special importance because it was shown that low-velocity impacts may cause internal damage within composite structures which, although invisible, may seriously reduce loading capacity of the material. The improved understanding of impact performance will enable vehicle engineers to design and test composite products more cost effectively.



Fig.6. Laboratory for impact tests of composite structures in DIEM laboratory in Bologna

**DIEM has laboratory for impact test of composite structures in Bologna** (Fig. 6). The laboratory is used for the purposes of testing of marine vessels and vehicle industry components. **Complementarity of the research programs between MFKV and DIEM** led to development of research project "Alma@SeRViCe" that promoted application of composite materials in airborne, marine, railway and automotive vehicles.





Fig.7. Researchers from MFKV and DIEM during impact tests, Bologna, February 2011

Seconded researcher from MFKV was included in test campaign for investigation of impact behavior of air-intake manifold manufactured by company "Magneti Marelli" in tasks 13 (November 2010) and 15 (February 2011). It brought him experience in application of piezoelectric and photoelectric sensors. Besides, it brought knowledge of specific aspects of impact testing of structures made of composite materials, which, during impacts, behave in a different way compared to metal structures.

### Project development

**The basis for further collaboration between DIEM and MFKV represent common research projects developed during the project "SeRViCe".** Although the activity presents institutional development and management staff education, it is included in this report for two reasons: 1) because it was carried out by researchers that took part in secondments for improvement of experimental methods for investigation of railway vehicles 2) because the content of the projects is inspired by knowledge and experiences gained during secondments for improvement of experimental methods for investigation of railway vehicles.

The common characteristics of all proposed projects is that they are **oriented towards the needs of local industry** and that they present an effort to further spread influence and knowledge of Railway Vehicles Center and Faculty of Mechanical Engineering Kraljevo.

The project proposals were developed during the tasks 2-7 (March-October 2009) and during the task 16 (April 2011). The following project proposals were developed:

- acronym "Alma@SeRViCe", full title "Materiali compositi al servizio del trasporto ferroviario" (Composite materials in service of railway transport), MISE-ICE-CRUI 2008 call for proposals-regional projects of region Emilia-Romagna, approved for realization in period 2009-2011, partners DIEM department of University of Bologna (Bologna, Italia), "BMC AirFilters" (Medicina-Bologna, Italia), "Studio Pedrini" (Bologna-Italia), MATMEC (Bologna-Italia), MFKV (Kraljevo, Serbia), Engineering Software Laboratory-University of Kragujevac (Kragujevac-Serbia), LMTA, Laboratory for theoretical and applied mechanics-Universidade Federal Fluminense (Niteroi-Brazil), Department of Aeronautical and Vehicle Engineering-KTH university, (Stockholm-Sweden), CRA-Department for Materials of University of Cranfield (Great Britain);
- acronym "Adria-Hub", full title "Bridge technical differences and social suspicions contributing to transform the Adriatic area in a stable hub for a sustainable technological development", proposed for realization in period 2010-2013, partners University of Bologna (Italia), "Alma Laurea" (Italia), Faculty of Mechanical Engineering Kragujevac (Serbia), Faculty of Mechanical Engineering Kraljevo (Serbia), University of Arts Belgrade (Serbia), Faculty of Mechanical Engineering Niš (Serbia), University of East Sarajevo (Bosnia and Herzegovina), University of Dubrovnik (Croatia), University of Rijeka (Croatia) and Faculty of Civil Engineering-University of Zagreb (Croatia);



Fig. 8. Meeting of team which prepared project proposal "SimulCarve", Ivrea, March 2009

- acronym "SimulCarve", full title "Integrated design methodology for manufacturing systems in non-conventional material processing ", "Manunet 2009" call for proposals - inter-regional EU projects, proposed for realization in period 2009-2011, partners "Wires Engineering" (Italy), "C3M" (Slovenia), SUPSI-ICIMSI (Switzerland), "SCABA SA c/o Cerini Aldo" (Switzerland), Technical University of Cluj-Napoca (Romania), University Politehnica of Bucharest (Romania), "Transilvania University of Brasov" (Romania) with DIEM and MFKV as consulting partners;
- acronym "IMPuls", full title "Innovation Management for new Products", call RSEDP-2-regional development projects financed by EU, approved for realization in period 2011-2013, partners MFKV (Serbia), DIEM (Italy), Regional Chamber of Commerce Kraljevo (Serbia), City of Kraljevo (Serbia), Regional Centre for Small and Medium Sized Enterprise Development Krusevac (Serbia);
- acronym "ATCSerbia", full title " Automotive Training Centre for Central Serbia ", call RSEDP-2-regional development projects financed by EU, approved for realization in period 2011-2013, partners University of Bologna (Italia), Faculty of Mechanical Engineering Kragujevac (Serbia), Faculty of Mechanical Engineering Kraljevo (Serbia), IAL Friuli Venezia Giulia (Italy), Technical Faculty in Cacak (Serbia), "Fiat Automotive Serbia", Fiat Group (Italy), "Zastava" Holding, (Serbia);
- acronym "2CC", full title "Two Continents in Composites Knowledge Transfer", call FP7-People - IRSES 2011, proposed for realization in period 2011-2015, partners DIEM (Italy), MFKV (Serbia), Faculty of Mechanical Engineering Kragujevac (Serbia), faculty of Technical Sciences Novi Sad (Serbia), Composites Laboratory of Engenharia Metalurgica e de Materias-COPPE-Universidade Federal do Rio de Janeiro (Brazil), Laboratorio de Química de Materiales Departamento de Construcciones y estructuras - Facultad de Ingenieria - Universidad de Buenos Aires (Argentina).

### Dissemination and promotion

While it was not primary goal of the activity, seconded researchers used opportunities to take part in activities which enabled dissemination and promotion of the activity, project "SeRViCe", FP7 projects and international collaboration in general.

Some of events where the seconded researchers promoted the collaboration between MFKV and DIEM were:

- visit to "Course on Experimental Methods in Applied Mechanics" in Bertinoro, 11<sup>th</sup> of March 2009, presentation to young researchers who participated in course, and meeting with prof. dr Romano Prodi, former President of European Commission
- course "Sensors for automated machines" for engineers from company SCM, 19-30<sup>th</sup> of October 2009

- course "Sensors and actuators for automated machines" for engineers and technicians, 25<sup>th</sup> of January-5<sup>th</sup> of February 2010



Fig. 9: Z. Šoškić (left) in conversation with prof. R. Prodi (right), Bertinoro, March 2009

- seminar "Experimental Analysis of Mechanical Structures" for PhD students of MFKV, 6<sup>th</sup> of September 2010



Fig. 10: Seminars for advanced students in Kraljevo, September 2010 (left), and Bologna, February 2010 (right)

- lecture "Alma Mater Studiorum and Serbian universities - A brief overview of a success story" held by dr Zlatan Šoškić in castle of Bertinoro, at forum "Forum Sulla Cooperazione Istituzionale ed Economica tra Italia e Serbia", 24<sup>th</sup> of March 2011

Finally, in the course of the project seconded researchers visited numerous companies both in Italy and Serbia, learning about their present state, plans, problems and needs. Here is a list with some of companies that seconded researchers visited:

Italy:

- "Alstom", railway vehicles industry, Bologna
- "Magneti Marelli", automotive components, Bologna
- "Ducatti", motorcycles, Bologna
- "Studio Pedrini", engineering design, Bologna
- "Servomech", control system components, Bologna



Fig.11. Visit of seconded researcher to the factory "SCM", Rimini, November 2010

- "Technipes", packing machines, Bologna
- "IMA", packing machines, Bologna
- "Mariner", boats, Forlì

- "Fomet", foundry, Imola
- "Wires", stone processing equipment, Ivrea
- "SCM", wood processing machines, Rimini
- "Robopac", packing machines, Rimini

France:

- "Alstom", railway vehicles industry, Paris

Serbia:

- "Wagon Factory Kraljevo", railway vehicles industry, Kraljevo
- "Zastava FAS", automotive factory, Kragujevac
- "GIR", wood processing factory, Kraljevo
- "Giugia", wood processing factory, Kraljevo
- "Forma Ideale", wood processing factory, Kragujevac

## Summary of results

**The most important result of the secondments is developed collaboration between MFKV and DIEM**, which may be expressed through common research projects and scientific papers which are the consequence of the project activities.

During the project course, researchers that participated in secondments submitted **six common project proposals**, and three of them are approved for realization. Five of the proposed projects include experimental studies of mechanical structures, and are based on the collaboration developed during the secondments in field of experimental methods in railway dynamics. One of the projects which are the outcome of the secondments in field of railway vehicles engineering (Alma@SeRViCe), is already finished, and two other projects ("IMPuls" and "ATCSerbia") are in course.

In course of the project and immediately after the end of the project, researchers from MFKV and DIEM submitted **eight common papers on international conferences** and **three common papers in international scientific journals**. Five of the papers presented at conferences, and all three papers submitted to magazines, are the results of research performed during secondments in field of experimental methods in railway dynamics.

A very important consequence of the secondments performed at University of Bologna is **orientation towards research driven by industry needs**. Participation of University of Bologna is of critical importance for this result, because Serbian industry, and especially industry in surroundings of Kraljevo, is not strong enough to provide permanent research needs for continuous industrial development projects at MFKV; therefore, participation of MFKV researchers in DIEM industrial projects provides necessary complement of industrial challenges and projects.

Two-way secondments between MFKV and DIEM in field of experimental methods of railway dynamics were performed in total extent of 11.5 research-months. MFKV researchers spent 6.5 research-months working at DIEM, while the researchers from DIEM spent 5 research-months working at MFKV. While the **total extent of two-way secondments is for 2.5 months smaller than the planned amount**, the effect of the reduction was more than **compensated by strong presence of researchers from DIEM at MFKV**. In collaboration between developed universities and universities from regions of convergence, it is usual practice that the ratio of secondments is 1:3 or even 1:4. In this case, due to permanent engagement of researchers from DIEM, **the ratio was more close to 1:1**. Besides, in common collaboration between MFKV and DIEM was also performed the activity "Two-way secondments for theoretical methods of mechanical structures and components fatigue", **complementary** to this one, in which the amount of two-way secondments between the same institutions is **increased** from 9 to 11.25 research months. In this way, **the total amount of planned engagement in secondments for the project is completely realized**.

The timing of the activity was adjusted with respect to the project plan, because it was affected by the schedules of school year and vacation periods at MFKV and DIEM. However, **all the planned tasks were finished before the end of the project.**

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